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and
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of OCEANOGRAPHIC SCIENCES

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LONG TERM GOALS

The general research statement of our proposal emphasized optimization of sonars and acoustic remote sensing systems by coupling state of the art, physics based, signal and array processing and the education of students in ocean acoustics. This has been accomplished i) by leading the Navy S&T program to implement the Acoustic Testbed now under contract for deployment as well as the DARPA Robust Passive Sonar program, ii) conducting the ONR Geoclutter Experiment which clearly identified the significant contribution of submerged objects in bottom reverberation and iii) the mentoring of students and postdoctoral associates.

OBJECTIVES

The objectives are essentially the same as the long term goals.

APPROACH

There have been many components to the work sponsored. All have a common approach where the propagation physics is embedded into the signal and array processing. This concept is important for long range, low frequency and shallow water acoustics where there may be significant coupling among the modes and/or rays. Often this is labeled “full field” or “matched field” processing. One of the important issues for this is the coherence supported by the environment. This is a key issue as the impact of random inhomogenities in the ocean due to internal waves, solitons, boundary roughness and motion all are well known to degrade sonar performance. In many situations the various components of the propagation decohere or cannot be well measured (insufficient aperture and/or observation “snapshots), so the additional performance of a physics based approach can not be supported since this leads to too much signal gain degradation. Adaptive systems are particularly sensitive to this. Exploiting the propagation physics can lead to significant gains by avoiding mismatch as well as the potential for source localization and environmental parameter estimation (tomography). Coherence

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14. ABSTRACT
The general research statement of our proposal emphasized optimization of sonars and acoustic remote sensing systems by coupling state of the art, physics based, signal and array processing and the education of students in ocean acoustics. This has been accomplished i) by leading the Navy S&T program to implement the Acoustic Testbed now under contract for deployment as well as the DARPA Robust Passive Sonar program, ii) conducting the ONR Geoclutter Experiment which clearly identified the significant contribution of submerged objects in bottom reverberation and iii) the mentoring of students and postdoctoral associates.

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and the potential to use physics based array processing for nulling discrete interference was one of the principal concerns in the design of the acoustic testbed.

Most of the literature on scattering implicitly assumes a free space environment. In a waveguide such as for shallow water there are many modes and/or rays so there is a much more complicated process for both backscatter (usually the specular) and forward scatter.

Moreover, all the inhomogeneities mentioned above lead to decoherence and reduced capability for an active sonar. The approach for the backscattering in a waveguide is to use a model which leads to a diagonally dominant population with an exponential decay of the coherent components. This leads to models for the reverberation and forward scatter for the waveguide signal. Often the forward cross section is modeled Babinet's Principle, which is appropriate for fully coherent propagation; however, when there is scattering one must consider the extinction of the object signal which reduces the image coherence in the far field.

Performance predictions are an important issues in the design of a sonar system. Often these are described using performance bounds since exact analyses are often intractable.
We have used a Cramer-Rao (CR) bound approach to this. The first analysis considers the impact of multiple snapshots. In the limit of high SNR's the CR bounds implies simply adding the snapshots incoherently; however, this is not optimum method at low SNR's with multiple snapshots. In the second approach we have formulated a CR bound which is applicable for both passive and active sonars for operations spanning from fully coherent to completely saturated environments.

Finally, we analyzed the performance of acoustic communication systems. These systems typically operate at high frequencies. For this the approach is to incorporate the physics in the scattering function for the propagation.

RESULTS

Several topics concerning the coupling of propagation physics and signal and array processing for sonar systems were pursed with the SECNAV/CNO Chair-Scholar support. Two are discussed below because of the page constraints.

The Acoustic Observatory Working Group met over a two year period to develop a the rationale for an acoustic observatory (later renamed and acoustic testbed) and a notional array design which provide fundamental observations leading to enhanced performance for Navy sonar arrays. We consider getting the Navy to support the deployment of this system to be a significant accomplishment since it will provide data in a very well calibrated environment to support basic research on sonar system performance. The importance of the propagation physics for the signals and ambient noise, the signal and array processing to mitigate the impact of strong discrete interference and coherence models are all part of the testbed design. Figure 1 illustrates the "strawman" proposed to ONR. The suggested location is off the east coast of Florida off of Ft. Lauderdale.

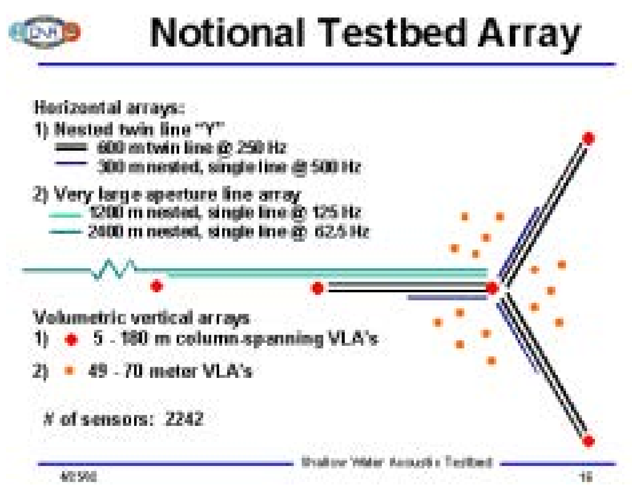

Figure 1: Shallow Water Acoustic Testbed (proposed): The array has three horizontal line arrays (HLA) with 300, 600 and 1200 m apertures with spacings for 62.5, 125. and 250. Hz. There is one 2400 m (HLA) for large aperture coherence. 5 water column spanning and 49 seventy meter vertical line arrays are included. Geophone arrays and plus temperature and current sensors provide environmental data.

Figure 2 indicates results for a pressure release sphere as a target comparing the effects of free space a waveguide on the backscattering. The left illustrates free space scattering while the left those obtained in a waveguide.

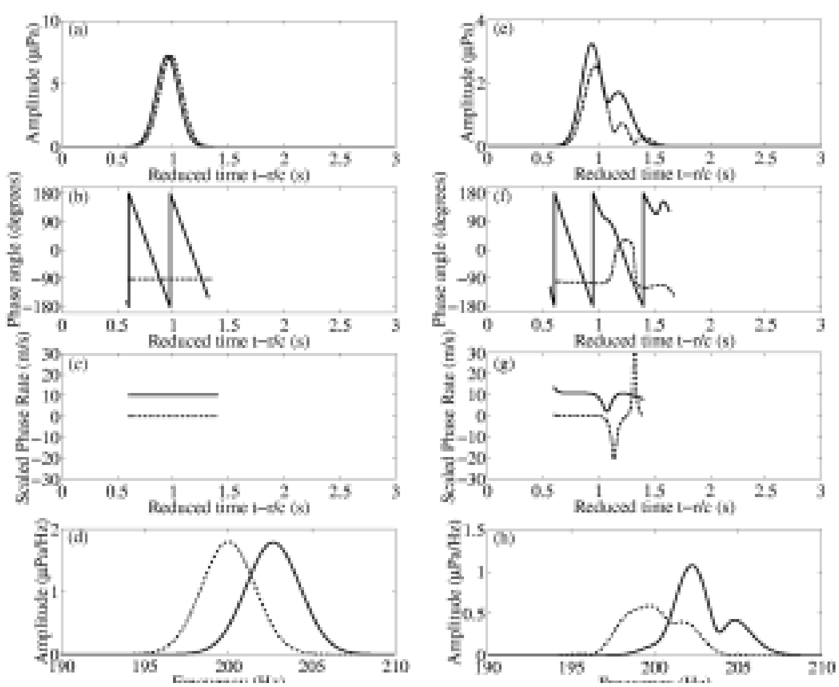

Figure 2: Backscattering from a sphere – comparison between free space (left) and a waveguide (right) for 200 Hz and ka=12. Dotted line-stationary target, solid line-10 m/s source. Top row: Complex envelope amplitude; second: complex envelope phase: third: phase rate, or apparent radial speed; bottom: received spectra.

IMPACT

The support provided by the SECNAV/CNO Chair-Scholar has had the technical impact described above. The Acoustic Testbed will be an important Navy S&T asset which already has the support of N77 to advance ASW. The models for propagation in a waveguide incorporate all the physics for both forward and backscattering. Probabably the most important impact is very long range – 5 graduate students with (4 PhD's and 1 SM degrees) and 2 postdocs have entered the field of ocean acoustics.

TRANSITIONS

The SENAV/CNO Chair was on the leaders of the Acoustic Observatory Working Group which has led to the ONR Shallow Water Acoustic Testbed in Code 321/US and the DARPA Robust Passive Sonar program.

RELATED PROJECTS

This work under the SECNAV/CNO Chair-Scholar Grant is related to the Acoustic Observatory Testbed Array now planned for deployment by ONR whose focus is to determine the limits of passive and active sonars when the physics for the propagation and noise are incorporated. It is also related to several ONR programs as well a NASA one. These include "Stochastic Matched Field Processing and Array Processing in Snapshot Limited Environments," (Code 321US) , the ONR DRI on Uncertainty (Code 321OA), the North Pacific Acoustic Laboratory (Code 321), Geoclutter Experiment (Code 321OA) and "Using Acoustic Detection and Classification of Hurricanes," (NOAA/Seagrant) . In addition, the SECNAV/CNO Chair serves on the Submarine Superiority Technical Advisory Group (SSTAG) for N77 and ASTO – PEO Undersea Warfare, the Fixed Surveillance Technical Advisory Group (FSTAG) for SPAWAR, the Program Assessment Panel for N74 . He is also a member of the Naval Studies Board and the Ocean Studies Board and has been on the panels for Undersea Weapons (NSB), Mines and Mine Countermeasures (NSB) and the Use of Environmental Information in Naval Operations (OSB).

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